



US006603313B1

(12) **United States Patent**  
**Srnka**(10) **Patent No.: US 6,603,313 B1**(45) **Date of Patent: Aug. 5, 2003**(54) **REMOTE RESERVOIR RESISTIVITY MAPPING**(75) **Inventor: Leonard J. Srnka, Houston, TX (US)**(73) **Assignee: ExxonMobil Upstream Research Company, Houston, TX (US)**(\*) **Notice:** Subject to any disclaimer, the term of this patent is extended or adjusted under 35 U.S.C. 154(b) by 18 days.(21) **Appl. No.: 09/656,191**(22) **Filed: Sep. 6, 2000****Related U.S. Application Data**(60) **Provisional application No. 60/154,114, filed on Sep. 15, 1999.**(51) **Int. Cl.<sup>7</sup> ..... G01V 3/02; G01V 3/08; G06F 19/00**(52) **U.S. Cl. .... 324/354; 324/359; 702/5**(58) **Field of Search ..... 324/354, 357, 324/359, 332, 334, 336, 337, 344; 702/5, 6, 7, 11**(56) **References Cited****U.S. PATENT DOCUMENTS**

3,727,231 A	4/1973	Galloway et al.	
4,247,821 A	1/1981	Buselli et al.	324/336
4,446,434 A	5/1984	Sternberg et al.	324/363
4,535,293 A	8/1985	Rocroi et al.	324/336
4,617,518 A	10/1986	Srnka	324/365
4,633,182 A	12/1986	Dzwinel	324/335
4,875,015 A	10/1989	Ward	
5,563,513 A	10/1996	Tasci et al.	324/359

**FOREIGN PATENT DOCUMENTS**

RU 2084929 7/1997

**OTHER PUBLICATIONS**

Buselli, G. et al, "Robust Statistical Methods For Reducing Sferics Noise Contaminating Transient Electromagnetic Measurements", *Geophysics*, v. 61, pp. 1633-1646, 1996.

Egbert, G. D., "Robust Multiple-Station Magnetotelluric Data Processing", *Geophys. J. Int.*, v. 130, pp. 475-496, 1997.

Caldwell, T. G. et al, "The Instantaneous Apparent Resistivity Tensor: A Visualization Scheme For LOTEM Electric Field Measurements", *Geophys. J. Int.*, v. 135, pp. 817-834, 1998.

Zhdanov, M. et al, "Three-Dimensional Quasi-Linear Electromagnetic Inversion", *Radio Science*, v. 31, pp. 741-754, 1996.

Newman, G. A. et al, "Three-Dimensional Massively Parallel Electromagnetic Inversion -I. Theory", Report SAND96-0582, Sandia Nat'l Labs, 1996 and *Geophys. J. Int.*, v. 128, pp. 345-354, 1997.

(List continued on next page.)

**Primary Examiner—Walter E. Snow****(74) Attorney, Agent, or Firm—J. Paul Plummer**(57) **ABSTRACT**

A method for surface estimation of reservoir properties, wherein location of and average earth resistivities above, below, and horizontally adjacent to the subsurface geologic formation are first determined using geological and geophysical data in the vicinity of the subsurface geologic formation. Then dimensions and probing frequency for an electromagnetic source are determined to substantially maximize transmitted vertical and horizontal electric currents at the subsurface geologic formation, using the location and the average earth resistivities. Next, the electromagnetic source is activated at or near surface, approximately centered above the subsurface geologic formation and a plurality of components of electromagnetic response is measured with a receiver array. Geometrical and electrical parameter constraints are determined, using the geological and geophysical data. Finally, the electromagnetic response is processed using the geometrical and electrical parameter constraints to produce inverted vertical and horizontal resistivity depth images. Optionally, the inverted resistivity depth images may be combined with the geological and geophysical data to estimate the reservoir fluid and shaliness properties.

**33 Claims, 9 Drawing Sheets-**